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Evaluation of Pump Flow line A Failures using Reliability Techniques: A Case Study of Niger Delta Refinery Ltd.

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ABSTRACT

This research is aimed at evaluating the reliability of the pumps A for crude oil feed line of ND refinery limited located at Ahoada East LGA of Rivers State in Nigeria. The reliability study was investigated for five consecutive years on the different parallel crude oil feed lines A. the parameters that were evaluated include the mean time between failed (MTBF), reliability (R), unreliability (UR) the downtime (DT) the availability (A), unavailability (UA), failure rate (FR) for each of the components. The components under evaluation were the pumps A. The mean time between failures was evaluated, and it was investigated that the failure rate increases down the years as well as downtime. From the evaluation the result obtained showed that the failure rate increased from 0.0013 to 0.0059 for pump line A. From the evaluation, it is seen that each of the component increases with time apart from reliability and available which the rate decreases with increase in years, the decline in reliability and availability with time is attributed to usage and aging of the pump.

Key words: Reliability, unreliability, pump, failures, downtime, unavailability

1. INTRODUCTION

The functions of pump and valve in crude oil distillation cannot be over emphasized, from the feed line to the distribution line pumps and valve are need to regulate the flow of the fluid. The functionality of a pump can alter the flow process of a distillation unit and other fluid processes. Pumps and valves come in different form depending on the purpose and the usage. In the petroleum industry centrifugal pumps are mainly use since they are fairly expensive and are durable. Centrifugal pump always served the purpose for which it was procured in as much as it is operated and maintained according to the manufacturer specified procedure [1-2]. A pump or a valve can be said to have failed if it is functioning below the rating or has stop completely. There are several ways a pump or a valve can fail; some of the common modes include suction clog, no flow, vibration and excessive noise, leakage of fluid etc [3]. The reliability study is carried out for pump and valve of ND refinery limited. Pumps and valves are integral part of the refinery process, since a

failure of any or either of the components will cause a downtime and high maintenance cost [4]. Currently the company is practicing preventive maintenance for its components. Due to incessant failures of the pumps and valves the maintenance department were performing corrective maintenance in conjunction to the preventive strategy and this has increase the cost of maintenance significantly [5].

Equipment failure of an instrument and mechanical equipment in the oil industry is inevitable [6]. The rate at which a piece of equipment fail is a major concern to the operator, the company as well as the environment, since the failure of equipment can lead to a near missed, mishap, incidence as well accident, hence the reliability study of plant in engineering management is imperative [7]. Recently the methods used by maintenance Engineers to evaluate the failure and the maintenance procedure to each equipment can be determined by the maintenance cycle times as stated in the maintenance manual, also the Failure Mode and the Effect Analysis (FMEA) methods or technique is used in an oil refinery to choose equipment (machine) in order to initiate preventive maintenance strategy. Preventive maintenance of equipment or machine is time-dependent. The maintenance period of a machine is a function of both the production quality and schedule [8]. The reliability and the production capacity of a machine can be found in the control chart or the product manual which may indicate when the machine will start failing or deteriorating whenever the average performance of the system changes. The failure of a plant can alter production either by stopping production or by altering the median of the production to change, thereby affecting the quality of the end product [9].

Reliability Engineering Technology (RET) is also utilized in-process production machines by considering individual components of the plants or equipment. The Mixed integral programming technique is one of the methods used by reliability Engineers to identify the highest profit that can be accrued from the Maintenance of a machine or equipment by stating the target function to be the maximum profit [10].

The ND refinery was designed to produce 1000bpd from crude oil ND flow stations. The inlet pump is designed to discharge the crude at a pressure of 9.3bar and a temperature of about 300^{o}C. This pressure is flow line discharge pressure, as all the pumped crude from the flow station are further store in a storage vessel at the ND storage tank which is in the same location. When the storage tank level is below the gauge level, the inlet flow rate is been compromised either by leakage by the delivery line or a glugging by sediment particles. To eliminate or remediate the situation maintenance model of reliability and probability techniques using fault tree and Poisson distribution, models are needed to evaluate the performance of pumps and the valves of the ND refinery. This study is aimed at evaluating the reliability of pumps and valves of a refinery using the case study of Niger Delta Refinery Limited.

2. MATERIALS AND METHODS

Study Area

Niger Delta (ND) Refinery Limited Company is located at Ogbele, Ahoada East Local Government Area of Rivers State Southern Nigeria. The facility was built initially to refine 1000bpd of crude oil to extract diesel (AGO) as shown in Figure 1.

The crude oil to be distilled or refine is sourced from her Ogebele and Otari oil field. Recently the plant has undergone expansion and upgrade which has increased production capacity to 11000bpd. Also the ND modular refinery has been expanded to produce 600,000 litres of gasoline per day. Consistent delivery of the 600000lpd of gasoline produce by ND refinery optimally will account for about 30% of the total gasoline produce by the State NNPC. According to an investigation carried out by Nigeria oil and gas industry Annual report of 2018, find out that NNPC produce 2043070L of gasoline per day.

Tests for Reliability

Reliability engineering is study of the durability and dependability of any engineering components, products and system. It is more of controlling and preventing of risk. Reliability engineering make use of various analytical techniques designed to enable engineers understand the failure mode and pattern of a system. Reliability is a measure of performance or dependence of a facility or a product within a specify time. This measure is a binary function (success or failure), in practice it is imperative to evaluate the period which the product is subjected to use such evaluation is called lifetime or failure time evaluation. Also reliability is seen as an attribute of a product that evaluates the performance of the product in line with the user [7]. Reliability hence, is refers to whether a test that is recurring on or about a study would give the same results or not [7-8].

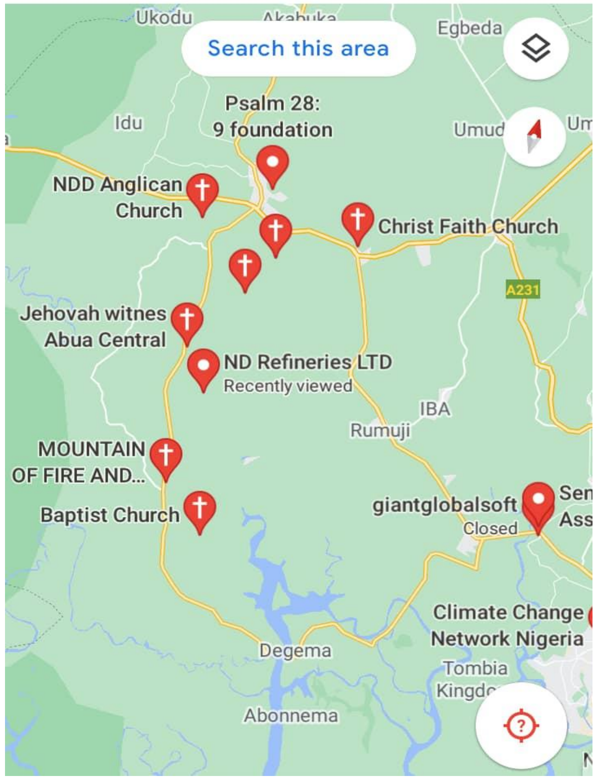

Figure 1: Study Area

Figure: 2: Data Collection

Methods of Data Collection

Data collection is the process of gathering useful information or material to enable a researcher carried out a research successful. The source of these data could be primary or secondary. The primary sources of data collection consist of first-hand information or raw data obtained by the researcher himself through the records and data collected from the company. Also the secondary data are most data obtained from literatures. For the purpose of this research the data used are primary data. That is information obtained by the research from Niger Delta Refinery (NDR) as shown in Figure 2. Also the failure are categories in the three stages such as failure due to infant mortality failure (IMF), constant failure rate (CFR) and wear out failures (WOF).

Table 1: Data for Failure and Repair Time for Pump A

	Failure/year	Repair Time (T) hours	Operating Time (Hour/Week)
1	10	2	161
2	13	2.5	154
3	15	3	133
4	25	3.5	126
5	30	5	105

Material Components

The following components are to be analysed in this study of Pumps.

Reliability Tools and Techniques

There are reliability tools and techniques methodologies available for failure of plant components. We have the Monte Carlo reliability model which can realistically assess plant condition when combined with cost, repair times and statistical events.

Mathematical Model Formulation and Development

The mathematical model for this research was evaluated using running time of five years (5) year (T) as well as the number of failures (N_F) ,N_S as the number of components still running at the stipulated time duration and N_0 as the total number of components.

Failure rate and mean time to fail or before to fail (MTTF AND MTBF).

The aim of quantitatively reliability is to ascertain the rate of failure compared or relative to time and the model of the failure rate using mathematical and probability density for the sole purpose of understanding the quantitatively aspect of failure . The basic fundamental approach is to establish the failure rate

$$N_0 = N_S + N_F \qquad (1)$$

Where, N_0 is number of components, N_s is number of components still operating and N_F is number of failed components

The ratio of failure components per sample sized is a measure of the unreliability of the components within a given time frame.

$$\varphi = \frac{NF}{N_0} \qquad (2)$$

The reliability of the components is given as

$$\Gamma = \frac{NS}{N_0} \qquad (3)$$

where: $$N_S = N_0 - N_F \qquad (4)$$

$$\Gamma = \frac{N_0 - N_F}{N_0} \qquad (5)$$

Γ=1-$\frac{NF}{N_0}$ (6)

Γ=1-φ (7)

The probability density function is given as

$$\text{Pdf} = \frac{dN_F}{dtN_0} \qquad (8)$$

Where, Pdf is the probability density function, dN_F is the change in the number of failure and dtN_0 is the number of components changing with time

Substituting equation (2) into equation (8) gives

Pfd =$\frac{d\varphi}{dt}$ (9)

Let pfd = f(t) (10)

F(t) = $\frac{dN_F}{dtN_0}$ (11)

Equation can be express as

f(t) dt = $\frac{dN_F}{N_0}$ (12)

upon integrating equation (13) gives the relationship for the unreliability in terms of probability density function Pdf(f (t)

$$\varphi(t) = \frac{N_{F(t)}}{N_0} = \int_0^t f(\tau)d\tau \qquad (13)$$

where the integral is the probability that a product will fail in the time interval

$0 \leq \tau < t$ (14)

Γ(t) = $\int_0^\infty f(t)d\tau$ (15)

Assuming that the probability of the failure tends to 1

$$\int_0^t f(\tau)d\tau = 1 \qquad (16)$$

Hazard Rate

The failure of a component or equipment in a plant can be attributed from inherent design faults or weakness, production and quality assurance related issues, other may be cause by operator usage, the maintenance polices as well as improper use of the equipment. Therefore the hazard rate (H(t)) is the number of failure per unit time per number of non-failed components still running at time (t)

H(t) =$\frac{N_F}{dt}.\frac{1}{N_S}$ (17)

Recall that :

Γ(t) = $\frac{N_{S(t)}}{N}$

F(t) = 1- Γ(t) = $\frac{N_{S-N_F}}{N_S}$ (18)

Dividing both sides by dt

$$\frac{F(t)}{dt} = \frac{d(N_0 - N_S)}{dtN_0} \quad (19)$$

$$\frac{dF(t)}{dt} = -\frac{1}{N_S}\frac{dN_S}{dt} \quad (20)$$

Therefore the hazard rate or the instantaneous failure rate

$$\text{h(t)} = \frac{f(t)}{\Gamma(\text{t})} \quad (21)$$

$$\text{h(t)} = \frac{N_0 - N_S}{N_0 dt} \quad (22)$$

Hazard rate is therefore a relative rate of failure but is in depended of the initial size of the components.

$$\text{h(t)} = -1\frac{d\Gamma(\text{t})}{\Gamma(\text{t})\text{dt}} \quad (23)$$

$$\text{f(t)} = \frac{-d\Gamma(\text{t})}{dt} \quad (24)$$

Integrating equation (24) from 0 to t

$$\int_0^t h(\tau) = -\int_0^t \frac{d\Gamma(\tau)}{\Gamma(\tau)\text{dt}} \quad (25)$$

$$\int_0^t h(\tau) = -\ln \Gamma(\text{t}) \quad (26)$$

$$\Gamma(\text{t}) = e^{-\int h(\tau)d\tau} \quad (27)$$

Total hazard rate THR

$$\text{H(t)} = \int_0^t h(\tau) \quad (28)$$

$$\Gamma(\text{t}) = e^{-\tau t} \quad (29)$$

Where τ is hazard constant rate, the (3.27) is an exponential distribution the most use prediction formula.

$$\tau = \frac{N_F}{T} \quad (30)$$

Where $\tau$is hazard rate or failure rate, N_F number of failed components, T is total time.

Mean Time between Failures (MTBF)

Another useful concept in reliability study is the mean time between /to failure (MTBF/MTTF). The only distinction between MTBF and MTTF is MTBF is use when referring to components that are repairable while MTTF is used when the components is not repairable. That is any faulty component is thrown away and replaced. The estimate of mean time between failure (MTBF) and mean time to failure (MTTF) are both measures of central tendency. It can be evaluated by taking the inverse of the hazard rate function.

Taking the inverse of equation (28), we have

$$\frac{1}{\tau} = \frac{T}{N_F} \quad (30a)$$

$$\frac{1}{\tau} = \delta \quad (30b)$$

Where δ is mean time between to failure (MTBF)

Total Mean Time between Failure (TMTBF)

To determine the total mean time between failures for pumps and valves for each year for five year period, we must first establish total failure per year (TFPy).

Thus,

(TFPy) = $\left[(\frac{T}{NF})_{y1} + (\frac{T}{NF})_{y2} + (\frac{T}{NF})_{y3} + (\frac{T}{NF})_{y4} + (\frac{T}{NF})_{y5}\right] x annualhr/yr$ (31)

(TFPy)= $\left[(\frac{1}{MTBF})_{y1} + (\frac{1}{MTBF})_{y2} + (\frac{1}{MTBF})_{y3} + (\frac{1}{MTBF})_{y4} + (\frac{1}{MTBF})_{y5}\right] x annualhr/yr$ (32)

where:

TMTBF = $\frac{annualhoursperyear}{Totalfailureperyear} = \frac{AHPY}{TFPY}$ (33)

Failure Rate (FR)

To determine the failure rate for each component, the mathematical expression stated in Equation (31) can be applied.

$\tau = \frac{N_F}{T}$

FR = τ (34)

Total Failure Rate (TFR)

The total rate (TFR) of each component is the sum of the failure rate in each year and is expressed mathematically in Equation (38).

$TFR = [(TFR)_1 + (TFR)_2 + (TFR)_3 + (TFR)_4 + (TFR)_5]$ (35)

Failure Rate Per Year (FRPY)

To estimate the failure rate per year (FRPY) for each component to be investigated, the mathematical expression for FRPY is expressed in Equations (39), (40) and (41).

FRPY = (failure rate for each component) x (annual hour per year)

= (FR) ($AHPY_1$) (36) $=\left(\frac{NF}{operational\ time}\right)(AHPY)$ (37)

FRPY= $\left[\frac{1}{MTBF}\right]$ (AHPY) (38)

Total Failure Rate Per Year (TFRPY)

Therefore, the total failure rate per year (TFRPY) is gotten by summing the failure rate of each component per year Equation (38).

$TFRPY = (FRPY_1) + (FRPY_2) + (FRPY_3) + (FRPY_4) + (PRPY_5)$ (39)

Reliability Model

To determine the reliability of each component, the mathematically expression is given as in Equation (30).

$\Gamma(t) = e^{-\tau t}$

$R = e^{-}(\frac{1}{MTBF})^{t} = e^{-\tau t}$

where: $\tau = \frac{N_F}{T}$ and $\tau = \frac{1}{MTBF}$

When as the reliability for each component for five year study is given as in Equation (13).

$$\Gamma = e^{-}\left[(\frac{1}{MTBF})_1 + (\frac{1}{MTBF})_2 + (\frac{1}{MTBF})_3 + (\frac{1}{MTBF})_4 + (\frac{1}{MTBF})_5\right]^{t} \quad (40)$$

Unreliability Model

To determine unreliability for each asphalt plant component, the mathematical expression is from equation (3.6)

$$\Gamma = 1 - \varphi$$

$$\varphi = 1 - \Gamma = e^{-}(\frac{1}{MTBF})_t \quad = 1 - e^{-\tau t} \quad (41)$$

Reliability Evaluation or Analysis of Standby –Line for ND Refinery Pumps and Valve System.

Since the ND refinery plant is built to run for several years it is necessary to evaluate the reliability parameter of the ND refinery pumps and valves system aim to ascertain the risk of continue to operate the pumps and valves in these conditions. The ND refineries pumps and valves are arranges in parallel manner, with a stand -by system with one unit of pump and vales operating and the other is waiting in a stand-by-mode for failure of either a pump or a valve in the first line or line A. Specific system is configured in such a way that, as soon as s failure occurs the operator switch to the stand-by unit.

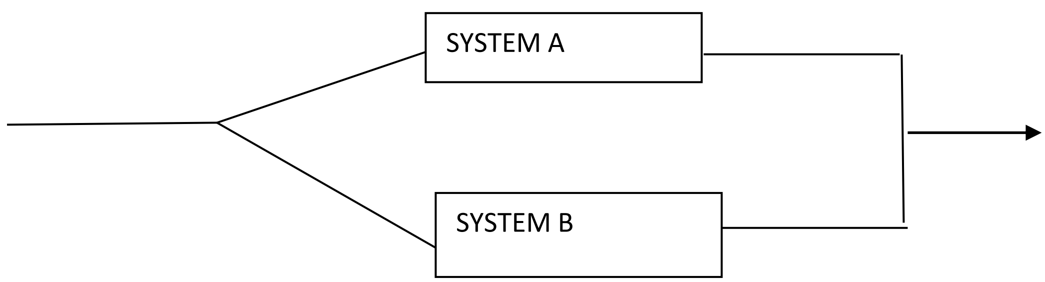

Figure 3: Parallel Arrangement of the Pump and Valve

$$r_{sb=e^{-t\tau_a}} + \left(\frac{\tau_a}{\tau_b - \tau_a}\right)\left(e^{-t\tau_a} - e^{-t\tau_b}\right) \quad (42)$$

Where, Rsb = reliability of stand-by line, τ_b = failure rate of line B and t = Operation *time*

Availability Model

To determine availability (A) of each pumps and valves component per year, the expression is given as in Equation (43).

$$A = \frac{uptime}{uptime + down\ time} \quad (43)$$

Unavailability

The unavailability (UA) for each component is determined by Equation (42).

$$UA = 1 - A = 1 - \left[\frac{uptime}{uptime + down\ time}\right] \quad (44)$$

Cost Evaluation

Cost analysis is one of the important aspect reliability analysis or evaluation. The main purpose of the analysis is to the reliability into money. This is the money that will be used for plant maintenance management to justify improvements and avoid loss of the gross margin of the company. Though it is the duty of an engineer define the equipment failure rate and the risk pose by failure on the life of the equipment.

$$cou = cost_{spareparts} + cost_{labour} + cost_{loss\ of\ prduction\ time} \quad (45)$$

where COU is cost of unreliability (COU)

3. RESULTS AND DISCUSSION

Results

This research showcases the information gotten from ND refineries Nigeria limited on Pumps and Valves for a period of 5 years. The details of evaluation of the functional parameters are shown in this paper. .

Evaluation Analysis of parallel Pump A

Table 2: Data Collected from ND Refineries Distillation Column Feed Line pumps A

Years	Failure/year	Repair Time (T) hours	Operating Time (Hour/Week)
1	10	2	161 (7728)
2	13	2.5	154 (7392)
3	15	3	133 (6384)
4	25	3.5	126 (6048)
5	30	5	105 (5040)

Table 2 shows the data collected for the pump line A for a period of 5 years which comprises of the failure rate per year, operating time per week and time to repair each breakdown per year.

To Evaluate the Operating Time Per Year for ND Refineries Distillation Column Feed line pump A

Operating Time Per Year = Operating Time per Week x 4 Weeks x 12 Months

For 1 year = 161 x 4 x 12 = 7728 hrs/y, for 2 years = 154 x 4 x 12 = 7392 hrs/y, for 3 years =133 x 4 x 12 = 6384 hrs/y, for 4 years =126 x 4 x 12 = 6048 hrs/y and for 5 years = 105 x 4 x 12 = 5040 hrs/y

Total operating times = 7728 + 7392 + 6384 + 6048+ 5040 = 32592 hrs/y

Mean Time between Failure (MTBF) for the pump on line A

MTBF = $\frac{Operating\ times}{no\ of\ failure}$

For 1 year = $\frac{7728}{10}$ = 772.8 hrs, for 2 years = $\frac{7392}{13}$ = 568.62 hrs, for 3 years = $\frac{6384}{15}$ = 425.6 hrs, for 4 years = $\frac{6048}{25}$ = 241.92 hrs and for 5 years = $\frac{5040}{30}$ = 168 hrs

Total mean time between failure for the for (pump) on line A for 5 year

= TMTBF = $\frac{Annual\ hours\ per\ year}{Total\ failure\ per\ year} = \frac{(Y1+Y2+Y3+Y4+Y5)}{10+13+15+25+30}$

= $\frac{772.8+568.62+425.6+241.92+168}{10+13+15+25+30}$

TMTBF = $\frac{2176.52}{93} = 23.4034 hrs/failure$

Failure Rate for the pump on line A per Year

Failure rate = $\frac{no\ of\ failure}{Operating\ times}$

For 1 year = $\frac{10}{7728}$ = 0.0013, for 2 years = $\frac{13}{7392}$ = 0.0018, for 3 years = $\frac{15}{6384}$ = 0.0023, for 4 years = $\frac{25}{6048}$ = 0.0041 and for 5 years = $\frac{30}{5040}$ = 0.0059

Total failure rate for 5 years = $\sum$ failure rate/year

= 0.0013 + 0.0018 + 0.0023 + 0.0041 + 0.0059 = 0.0154/year

Lost Time Per Year for the Pump in line A (down time)
Lost time per years = failure of each component per year x Repair Time

For 1 year = $10 \times 2 = 20$, for 2 years = $13 \times 2.5 = 32.5$, for 3 years = $15 \times 3 = 45$, for 4 years = $25 \times 3.5 = 87.5$ and for 5 years = $30 \times 5 = 150$

Reliability Analysis (R) for Pump on line A
Reliability (R), $\Gamma = e^{-\lambda t}$

Where, τ = failure rate/year, t = operating time/year

For 1 year = $e^{-0.0013*1}$ = 0.9987, for 2 years = $e^{-0.0018*2}$ = 0.9964, for 3 years = $e^{-0.0023*3}$ = 0.9931, for 4 years = $e^{-0.0041*4}$ = 0.9837 and for 5 years = $e^{-0.0059*5}$ = 0.9709

Unreliability (UR) for Pump for Line A
Unreliability (φ) : $\varphi = 1 - \Gamma = e^{-}(\frac{1}{MTBF})_t \quad = 1 - e^{-\tau t}$

Where, R = Reliability

For 1 year = 1 – 0.9987 = 0.0013, for 2 years = 1– 0.9964 = 0.0036, for 3 years = 1 – 0.9931 = 0.0069, for 4 years = 1 – 0.9837= 0.0163 and for 5 years = 1 – 0.9709 = 0.0291

Reliability (R) of Stand-by-line
$r_{SB=e^{-t\tau_A}} + \left(\frac{\tau_A}{\tau_B - \tau_A}\right)(e^{-t\tau_A} - e^{-t\tau_B})$

Where, RSB = reliability of stand-by line

$\tau_A =$ Failure rate of line A
$\tau_B =$ Failure rate of line B
$t =$ Operation $time$

$r_{SB(1)=e^{-0.9987\times 1}} + \left(\frac{0.0013}{0.0019-0.0013}\right)(e^{-0.9987\times 1} - e^{-0.9981\times 1}) = 1$

$r_{SB(2)=e^{-0.9987\times 1}} + \left(\frac{0.0018}{0.0019-0.0018}\right)(e^{-0.9987\times 2} - e^{-0.9981\times 2}) = 1$

Availability (A) Pump on Line A
Availability (A) = $\frac{uptime}{uptime + downtime}$

For 1 year = $\frac{7728}{7728+10}$ = 0.9987, for 2 years = $\frac{7392}{7392+13}$ = 0.9982, for 3 years = $\frac{6384}{6384+15}$ = 0.9976, for 4 years = $\frac{6048}{6048+25}$ = 0.9959 and for 5 years = $\frac{5040}{5040+30}$ = 0.9941

Unavailability (UA) for Pump on Line A
Unavailability = 1 – A
Where, A = Availability

For 1 year = 1- 0.9987 = 0.0013, for 2 years = 1- 0.9982 = 0.0018, for 3 years = 1- 0.9976 = 0.0023, for 4 years = 1- 0.9959 = 0.0041 and for 5 years = 1- 0.9941 = 0.0059

Table 3 shows the summary data evaluated from the pump component on line A for 5 year period of reliability analysis.

Table 3: Summary Results of Reliability Parameters for Pump on Line A

Parameters	**Period (Year)**				
	1	**2**	**3**	**4**	**5**
Uptime(UT) (hrs)	7728	7392	6384	6048	5040
Study Interval (SI) (hrs/year)	8760	8760	8760	8760	8760
MTBF	772.8	568.62	425.6	241.92	168.0
Failure Rate (FR)	0.0013	0.0018	0.0023	0.0041	0.0059
Downtime (DT) (hrs)	20	32.5	45	87.5	150
Reliability (R)	0.9987	0.9964	0.9931	0.9837	0.9709
Unreliability (UR)	0.0013	0.0036	0.0069	0.0163	0.0291
Availability (A)	0.9989	0.9982	0.9976	0.9959	0.9941
Unavailability (UA)	0.0013	0.0018	0.0024	0.0041	0.0059

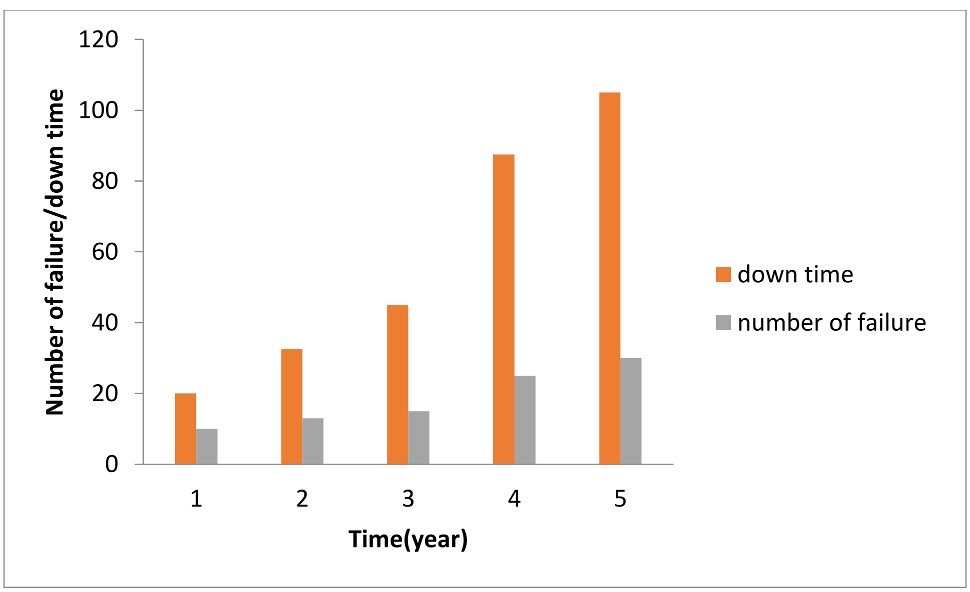

Figure 4: Number Failure of the Pump on line A with its Down Time against Time (Years)

Table 3, illustrate the summary of the functional parameters of the Pump on line A, from the evaluated pump values, it is observed that there is a decline in the uptime (operating time) as the year increase from the 1st year to the 5th year. Also, the mean time between failures shows a decrease this could be attributed to the decrease in operating time. Likewise the down time (DT)

increases as with increase in years as the component ages with years. There was also an increase in the failure rate form their 1st year to the 5th year.

Figure 4 is a vertical bar chart illustrating the rate of failure of a parallel pump on line A with a corresponding down time. Figure 4 illustrates the failure and the down time of a parallel pump on line A. As the year increases, the number of failures of the pump was observed to be increasing from the 1st year to the 5th year. The failure recorded in the early years could result to failures due to manufacture fault, but as the year progresses, the failure rate increases as well. Increase in the failure rate could also be accounted as a result of over usage and wear of the components. These failures cause increase in the down time since the down time is a function of the repair time and the number of failures. Therefore, as the rate of failure increases the down time increases significantly.

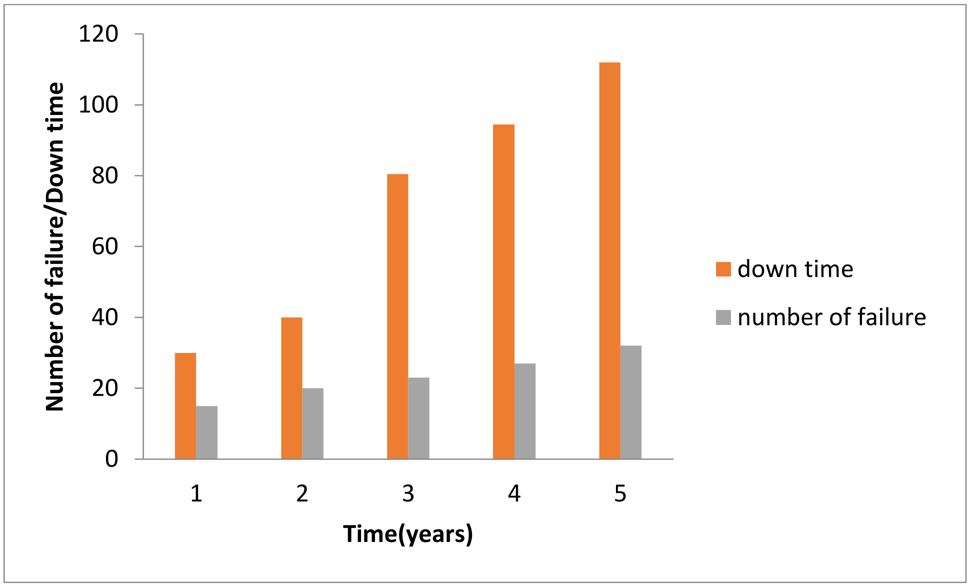

Figure 5: Number Failure of the Pump on line B with its Down Time against Time (Years)

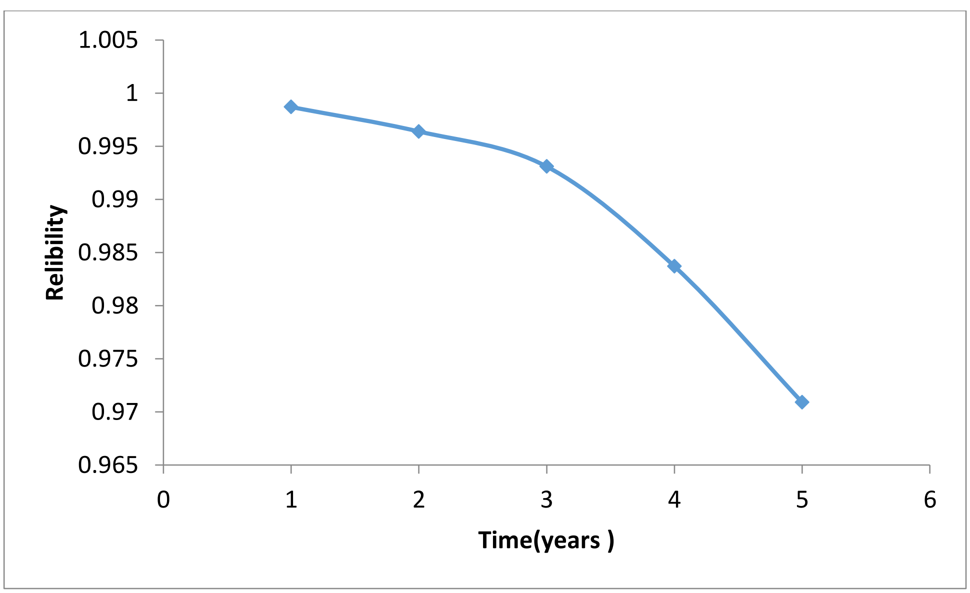

Figure 6: Reliability of Pump on Line A with Its Down Time against Time (Years)

Figure 5 is a vertical bar chart illustrating the rate of failure of a parallel pump on line B with a corresponding down time. The analysis of the research on Figure 5 illustrates the failure and the down time of a parallel pump on line B. As the year increases, the number of failures of the pump was observed to be increasing from the 1st year to the 5th year. Also, the down time was increasing

alongside with the failing rate. The increase in the down time could be attributed to the failing components due to ageing of the pump and over usage. Increase in the failure rate could also be accounted as a result of over usage and wear of the components. These failures cause increase in the down time since the down time is a function of the repair time and the number of failures. Therefore, as the rate of failure increases the down time increases significantly.

Figure 6 illustrates the relationship between reliability of pump on line A with its down time and period of exposure (time). The result obtained reveals decrease in reliability with increase in time. This is an indication that the pump parameters deteriorates or wear-out with time. As the failure rate increases the reliability of the component decreases. It also confirms that reliability decreases with time this is due to the ageing of the components. Figure 6 demonstrates a steady decline in the reliability of the pump over five years period. In addition to the aging of the components there is an indication of shortage of experience workers, which contributed to high failure of the pump leading to a declined in reliability down the years. Also the random failure mode of pump A could be attributed to the variation of process parameters.

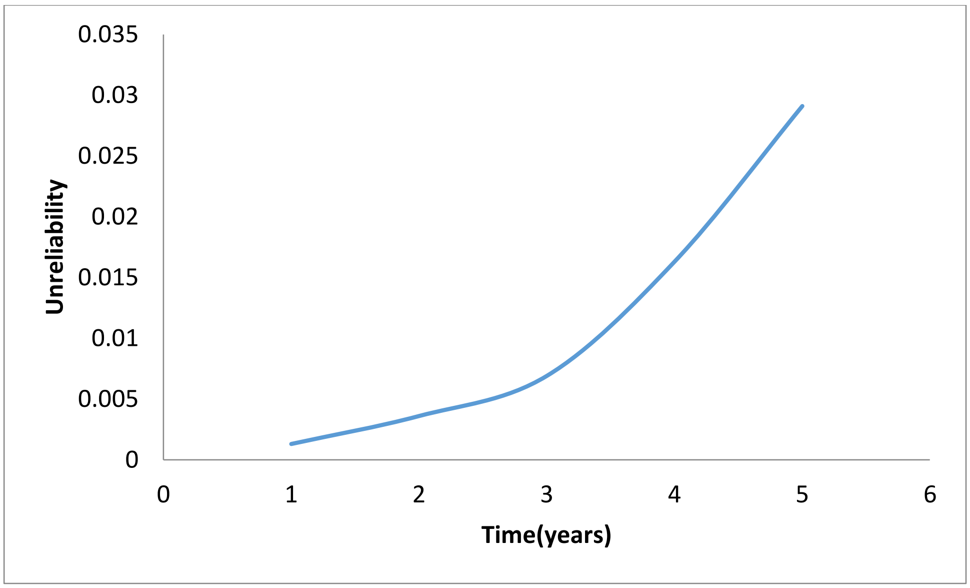

Figure 7: Unreliability of Pump on Line A with Its Down Time against Time (Years)

Figure.7 illustrates the rate of unreliability of the pump in line A with time. It is clear that the rate of unreliability of the pump is a reverse of the reliability as unreliability increases with time. This is an indication that the pump parameters deteriorates or wear-out with time. As the failure rate increases the unreliability of the pump increases. The unreliability is seen as the sum of the failure. It also a clear indication that unreliability increases with time this is due to the ageing of the components. Figure 7 illustrates a steady increase in the unreliability of the pump over five years period.

4. CONCLUSION

This research work has be set out to evaluate the performance of ND refineries pumps valves used in feed line to the distillation column operated in a parallel mode, one standby and the other active. Result obtained from the study reveals that the pumps used are highly efficient; because of the high reliability obtained across the years is a clear indication that pumps were reliable. The parameters investigated for five years were the failure rate of the pump, the downtime, reliability(R) and unreliability (UA), also the available (A) and unavailability of the pump were also evaluated from the data presented. From the analysis computed it is seen that the highest reliability was in the first year and the highest unreality was in the fifth year for all the four components pumps A this buttress that the reliability of the component were majorly time depended ,although other parameters were also responsible for the failure. The component failed in this order 30, 32 70, and 90 for pump A respectively. Whereas the reliability decreases down the years from 1st year to the fifth year for all the components with components in line A having the highest reliability of 0.998 for pump.

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Conflict of Interest

The author declares that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

REFERENCES AND NOTES

1. Ancel, A., Gross, D. & Cugliemi, L. (2010). Fatigue design for scroll compressor wraps, international compressor engineering conference
2. Barringer, H. P. (2003). A life cycle cost summary. In Proceedings of the International Conference of Maintenance Societies, 20–23. Buckinghamshire.
3. Beebe, R. (2004). Predictive Maintenance of Pumps Using Condition Monitoring. Oxford: Elsevier Advanced Technology
4. Chaurvedi S.K., Misra K.B. (2002). A hybrid method to evaluate reliability of complex system. *International Journal of Quality and Reliability Management*; 19(8/9), 1098-1112.
5. Condra, L.W. (2001). Reliability Improvements with Design of Experiments (2nd edition) McGraw-Hill, New York.
6. Fontaine, A. F. & Liegeois, O. (2007). Development of R 744 scroll compressor for low temperature refrigeration, *International Conference on Compressor and Their Systems* London.
7. Frenning, L. (2001). Pump Life Cycle Costs: A Guide to LCC Analysis for Pumping Systems, Executive Summary; Hydraulic Institute: Parsippany, NJ, USA; Europump: Brussels, Belgium; Office of Industrial Technologies Energy Efficiency and Renewable Energy, U.S. Department of Energy. 1–19.
8. Gulich, J. F. (2014). Centrifugal Pump. Berlin Heidelberg: Springer-Verlag.
9. Jameed-U, R., Rehman K. & Syed, M. Z (2009). Design and performance evaluation of pump system. *International Journal of Refrigeration*, 22(3), 235-243
10. Kan, M. Shan, Andy C. C. Tan, & Joseph Mathew, (2015). Rotating Systems - Journal of *Mechanical Systems and Signal Processing*, 62(3), 1-20.